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SPATIAL AND TEMPORAL ANALYSIS OF DECLINE IN DJELFA PINE FOREST (ALGERIA)

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ABSTRACT

Remote sensing data have allowed us to analyze the state of the forest cover and its evolution in the Djelfa area over a period from 1972 to 2009. Analysis method based on the use of satellite images Landsat MMS 1972, TM 1987 and Landsat ETM 2001 and 2009 has been used. Based on supervised classification coupled with field surveys, forest areas and ecological balance were determined for the years 1972, 1987, 2001 and 2009. Results obtained show that the canopy occupied 54524 hectares in 1972, 70391 hectares in 1987 to 59014 hectares in 2001. In 2009 the pine fell to 53283 hectares, the degree of degradation has detected a variable changes in the forests of the semi -arid area surveyed. The ecological balance of the forest cover is generally positive in 1987 with a rate of 21.8 %, while in 2001 and 2009, the regression is estimated at 16.5%. The increase in forest cover appearing on the 1987 satellite image shows an extension of reforestation made in the eighties under the Green Dam project, and suitable climatic conditions during these years. Classified sequences satellite images were used to estimate the loss of surface area over time, a total of approximately 24.30 % of the forest has disappeared.

The degradation causes of forest are multiple 2001 and 2009, the most important being the frequency of recorded droughts. The methodology introduced in this research has set up a base map that can be a management tool to consider a better protection of this fragile ecosystem.

KEYWORDS: Pine Forests, Decline, Djelfa, Algeria

INTRODUCTION

The importance of forests is a key link between the atmosphere, geosphere and hydrosphere (CCT, 2008). Currently forest stands in Algeria are under aggressive environmental dependence, which contributes not only to a change in the health of the tree but also to an ecological imbalance. In semi -arid areas, the forests Djelfa region are in degradation, for example, wood logging about 40,000 m^3 in 10 years within the of forest sanitation (CHAKALI, 2003).

Management and exploitation of forest resources require first, mapping and inventory of forest area. All mapping techniques is the science of remote sensing provides information about an object, territory or geographical phenomenon through the analysis of data acquired from a distance without direct contact with the object (GIACOBBO, 2000). The identification and monitoring of forest cover change means, has been, for some years, used for the analysis of vegetation in protected areas, particularly in tropical areas (JUSOFF *et al*, 2003).

Through this investigation we conduct a diagnosis of the state of forest cover by quantifying changes in forest areas, from the treatment and analysis of satellite images over the last 40 years. Monitoring the evolution of the forest

reserve of semi-arid Djelfa region through the detection of changes in forest areas, ensures continuous monitoring of the evaluation and integration of the results in database form.

The aim is to obtain reliable information on the spatial and temporal evolution of Aleppo pine forests in the Djelfa region. In addition to these static data and in order to improve its management, evolution cards (cuts, natural forests and reforestation) were produced by using the method of difference, and the classification vector. The results of multi- temporal study and existing data were integrated and structured in the form of a GIS (Geographic Information System). Mapping is a logical and scientific simplification of a much more complex reality, while highlighting the most significant facts (CERRARAS *et al*, 1990).

The availability of satellite images, the oldest one date from 1972, offers an opportunity to characterize the changes in forest cover. Mapping can be understood in several ways, the most important is the recognition of land cover from automatic interpretations of satellite imagery (LECKIE *et al*, 2002). These satellite records highlight the historical statements and the temporal evolution of the prospected forest cover.

The development of remote sensing and Geographic Information Systems (GIS) has generated a lot of hope for improved analysis of the environment, landscapes and their dynamics, thanks, on one hand, to a systematic vision macroscopic that provide satellites, and on the other hand to the ability of spatial analysis and modeling that include GIS (BONN, 1996).

MATERIALS AND METHODS

Study Site

The Djelfa area is part of Algerian highlands between 2° and 5° East longitude and between 33° and 35° north latitude. It covers a total area of 32280.41 km², it is 300 kms from the capital Algiers; it remains one of the steppe regions with a substantial forest heritage. Its geographic location gives it a privileged place within the North-South Algeria relations; it has a combination of forests distributed over a large part of its regional territory.

According to the Forests Conservation Department, the total forest area in the region is estimated at 214117 ha, which represents 6.63% of the total land area.

Analysis Methodology

Processing of Collected Satellite Images

The studied area is the scene of Landsat 30m resolution, images covering the region of Djelfa are taken at different times during the same dry season (1972, 1987, 2001 and 2009), the oldest MMS, a TM ETM and the last two, which are represented by 7 channels except the scene in 1972 which is represented by 4 channels and considered as the starting year of the analysis. These images are processed, interpreted and managed using MAPINPHO and ENVI software; the images are in ENVI format of a Tif extension. For studies using LANDSAT images, it is common to retain only three channels that are the most representative for the discrimination of forest types TM4 (near infrared), TM5 (infrared medium), and a channel visible (TM1 or TM3) LEVESQUE (1987), COLEMAN et *al* (1990), JOLY (1993). The combination of these bands can give maximum information in a minimum of channels. The panchromatic band (8) has reduced the image resolution to 15 meters. Satellite results are compared to references from the field.

Analysis and Study of Satellite Images

An image preprocessing was conducted to increase the readability of data and ensure proper acquisition of information to facilitate their interpretations. We proceed from a geometric images correction, with the geo-referencing and radiometric for contrast enhancement. The colored composition of the images is defined by the combination of channels; 2 for the green, with a wavelength (0.52 – 0.60mm) and for red channel 3 with a wavelength range (0.63 – 0.69mm) and the infrared with the channel 4 (0.75 – 0.90mm). The combination of these channels brings up the forest area in question (DESHAYES *et al*, 1990).

An important setting is applied using ENVI software image of 2001 compared to 1:50 000 topographic maps. Other images were wedged, according to the chosen picture. This procedure resulted in correct errors and ensures a consistent overlay images.

In a second part we deal with images in a classification of digital information provided by the software, it is the identification of spectral signatures and clustering in metric radio classes that the user will identify thematic classes. Thus the allocation of the set of pixels of the image of homogenous classes (WILMET, 1996). The most suitable method in determining the appearance of land units in the study area is the supervised model. The idea of identifying a homogeneous unit and use it in a supervised classification procedure seems to be the simplest approach (BOULAHOUAT *et al,* 1996). It is based on prior knowledge of the terrain and vegetation cover during reading routes. The method consists in performing successive sheets on a set of pixels, and selecting the points that determine a component of the soil in the region of Djelfa, all pixels belong to the same class. We finally make a cartographic synthesis selected through information acquired from land classes, provided to software and introduced in the satellite image. The choice of aims that serve as sampling that can lead to confusion between some components, especially between uncovered and little covered soils. Classification per pixel is not always good enough to allow the identification of vegetation (DE JONG *et al,* 2001). However this alternative is to take the information on a set of pixels, which must involve knowledge of the soil. The third part focuses on the identification of forest areas, the determination of land units takes place after the demarcation of forest areas, according to the digitalization advocated using software MAPINPHO treatment, determination of surfaces takes calculate the extent of the ecological balance of the four analyzed periods, leading to the assessment of forest cover during the period under consideration “Table 1”.

The last part focuses on the location of points in the decayed forest area. Several visits and surveys were conducted in all series of the pine forest of Senalba Chergui to delineate households most affected by dieback and draw information on the expansion strategy. In every decayed area, records of geographical coordinates were recorded and stored using a GPS that is based on a constellation of 24 satellites and providing a precise position (DUQUENNE *et al,* 2005). Statements are represented in the appendix, and they are adjusted on images taken in 2001 and 2009 to ensure and facilitate the comparison.

Climate Data Analysis

The climate of Djelfa area is Mediterranean continental type of xerothermic trend with a hot dry summer and a variably wet and cold winter. The evolution of annual rainfall amounts reported in “Figure 1”, illustrating variations recorded during those years.

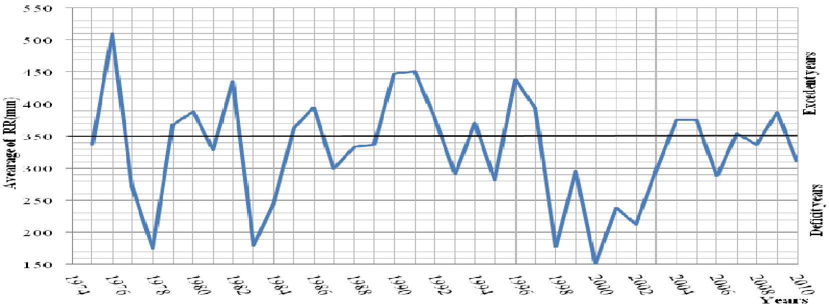

Figure 1: Temporal Variation of Rainfall in the Djelfa Area

Surpluses and deficits are calculated as a percentage of the average annual rainfall that characterizes the semi arid zone of the study area (350mm).

Rainfall amounts recorded in the years 1975 to 2010 show a very significant temporal irregularity. The highest rainfall recorded in 1976 with a value of 510 mm, or a surplus of 47,7 % by 2000 against is the driest with an amount of 150,7 mm, a gap of 359mm. Over the whole period, there are 20 years of water deficit. This reflects the irregularity of rainfall over time that is related to periods of drought, causing a disruption of the forest ecosystem, which actually translates an effect on the physiology of forest stands and become easy prey to disease pests and borers.

RESULTS

Presentation Classified Satellite Images

This research on the forest evolution cover is based on the processing and analysis of three data sources; air data, climate and site surveys. The satellite images are the foundation work, the rest of data will complete image interpretation in relation to the data field. It is a supervised classification in raster mode, this colorful composition analysis allowed us to identify 05 classes of land tenure; (dense forests, degraded routes, and alfa scrub, pine forests in association with juniper plantation and uncovered soil), similar classes are presented and grouped in the same category. This classification begins by determining the number of clusters and the selection of plots to achieve a synthesis based on a successive mapping selection of each class elements, based on the field information “Figure 2”,

The various steps established in the classification allowed to present in the final thematic maps, the considered five classes; dense forest represented by a black color, uncovered soil and degraded by a purple color, and scrub alfa green and brown represents pine stands and juniper course. This clearly reflects the components of the occupation of soil in the area of study, which leads to facilitate the interpretation of changes in forest cover in the region of Djelfa during the study period.

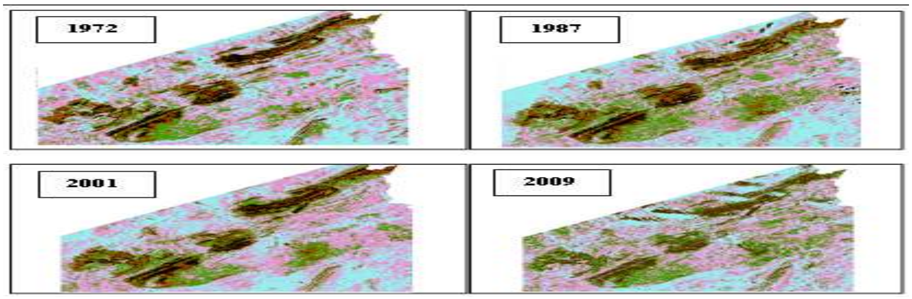

Figure 2: Temporal Presentation of Classified Satellite Images

In 1972, results issued from the classifications allow to quantify the land, including forest cover including dense forests and stands of pine and juniper representing 54524 hectares "Table 2" representing 25% of the forest area estimated by the Forest Conservation Department in 2012.

In 1987, a significant area of 70391 hectares is natural forests and reforestation projects initiated and implemented by the conservations of forest, representing 32% of the forest area of Djelfa. Similarly, the significant amount of rainfall recorded during the period from 1985 to 1997 with a renewed rainfall 350mm per year that exceed the quantities of 447mm and 451mm respectively were recorded in 1990 and 1991.

In 2001, the entire mapped area represents an area of 59014ha, i.e. 27.56% of the total forest area. A remarquable regression in areas of reforestation and plantation of Aleppo pine. In 2009, the total forest area occupied by pine forests is estimated at 53283ha, i.e. 24.88% of Djelfa forest area. The regressive evolution of the forest cover during the period of study is related to drought recorded since 1998. Such climatic conditions strongly favor fire, the installation and the proliferation of beetles, particularly bark beetles, *Tomicus destruens* (CHAKALI, 2007).

Temporal Evaluation of Forest Areas

The results of the surfaces of digitized forests during the period under consideration are summarized in “Table 1”.

Table 1: Chronology of Forest Area in the Region of Djelfa

Years / Forest Formations	1972		1987		2001		2009	
	Surface	**%**	**Surface**	**%**	**Surface**	**%**	**Surface**	**%**
Senalba Chergui	13180	24	13477	19	11263	19,08	10776	20
Senalba Guarbi	12959	23	12839	18	12133	20	9573	18
Sahary	16527	30	18516	26	20199	34	16782	31
Reforestation Sahary	-------	-------	780	1	808	1	789	1
Reforestation Moudjbara	-------	-------	9990	14	2498	4	2697	5
Djellal Chergui	1250	2	1399	2	1042	2	823	1
Djellal Guarbi	550	1	660	1	398	1	91	0,2
El Oust	1000	2	1175	1	811	1	540	1
El Guedid	7590	13	10032	14	8864	15	10679	20
El Oughba	981	2	1012	1	797	1	483	1
Degdegue	487	1	509	1	200	0,3	49	0,1
Total (ha)	**54524**		**70391**		**59014**		**53283**	
Ecological balance (%)	**16.89%**		**21.80%**		**18.28%**		**16.50%**	

Te ecological balance is the ratio of the forest area cover on the total region area. Regular ecological balance must be equal to or above 25%. From the outset the ecological balance is calculated at a lower rate to 25% between 1972 and 2009, however, this rate increased significantly between 1972 and 1987. Successive regression ecological balance between 1987 and 2009 is due to the situation marked by the evolution of recorded decline in several stations.

The result of classification and digitization of images with forest cover at different times shows an irregular variability of areas forest. An increase in forest area is marked in the eighties, which results in the various reforestation projects; Moudjbara, Sahary and plantings within the forests, especially forest Senalba Chergui. Between 1987 and 2009 an estimated 17107 ha decrease was noted, this loss of forest cover is justified by several factors, the most important is

marked by the combined action of prolonged drought followed by the attack of boring insects that contribute to the rapid deterioration of stands.

DISCUSSIONS AND CONCLUSIONS

Spatial and Temporal Analysis of Forest Formations in Djelfa Area

Recommended methods of treatment and analysis comprise three main steps; preprocessing of images, a numerical classification and identification of land use changes in the estimation of the area occupied by the forest. A first approach to the spatiotemporal dynamics can be achieved by a successive display of color compositions images studied over the vesting dates considered in order to have comparable phenological stages considered landscapes.

For a period of thirty-seven years, four satellite images expose three evolutionary states; the first image shows a comparison criterion and basis to interpret the images that follow. The second image features a vegetative recovery and revival of forest cover through reforestation programs under the Green Dam project. The two images on later periods show a significant decline in forest cover. All forest formations mapped and calculated from digitalization made surface led us to understand the major trends in the evolution of the elements of the forest cover in semi-arid areas.

Case of the Senalba Chergui Forest

The results of satellite images analysis covering the massive Senalba chergui show that the highest concentration was recorded in 1987, represented by a dark coloration which explains a recovery rate with a considerable density.

During the period from 2001 to 2009, forest Senalba Chergui, particularly the North Slope has been a sharp deterioration compared to the image of 1987. This regression takes the magnitude of the green the west affecting even young stands and stressed subjects and reforestation in forests. Surveys conducted in the forest show that stands older than 60 years are more the decayed. Noting that the digitized area in 2009 is estimated at 10776 hectares, or 20.4 % of the area recorded in 1987 has disappeared. As matter of fact, this estimate does not reflect the area actually deteriorated since digitalization cannot remove the decayed topics that are distributed within forest areas, which are considered in the satellite image as dense stands with healthy subjects. However, the emergence of low forest formations type that occupies half of the surface and shows the degradation knows this region. The wooded Aleppo pine, Holm oak and low scrub such as Rosemary, and other vegetation as Alfa clearly reflect the strong degradation of the forest heritage.

Case of Senalba Gharbi Forest

A time scale, Senalba Gharbi forest formations has not suffered a significant decline. The forest keeps a more stable pace occupying an area of about 12830 hectares in 1987. However 2001, the decline has exceeded 705 hectares, however this loss is greater in the year 2009 where it reached 2560 hectares, 22% of the recorded surface disappeared in 2001. Southeastern part of the forest is most concerned with the degradation of most stands limiting contour and forest edges are the most affected by the devastation areas.

The dark coloration present on the satellite image of 2009 includes dense stands with a good state but in reality are subjects degraded. This finding was confirmed by surveys conducted in the field particularly within these stands.

Case of Sahary Naturel Forest

The comparison between the images occupying Sahary pine plantation to different periods, highlights an estimated 2000 hectares in 1987 recovery in comparison with the satellite image of the original 1972 that the area occupied

at this time is 16527 hectares. In 2001, the estimated area surface 20199 hectares, clear staining on the northern edge of the forest degradation indicates the importance of the forest corridor, the light brown coloring inside the forest reflects the low density of these stands. In 2009, the surface degradation has affected more than 3417 hectares, approximately 17% of the recorded area in 2001 disappeared in 2009.

Based on these data, reforestation projects are expected to ensure better conservation and protection stands of Aleppo pine. Programs should be based on the concepts of forest management and land use. Subjects who resisted dieback should be used in practice and basic research for the use of their seeds in the future reforestation.

Case of Sahary Plantation

The project has been installed since the eighties, the satellite image of 1987 showed that young reforestation is characterized by a green color with thematic reality of young vegetation, an estimated 780 hectares area newly installed. In 2001, these stands are characterized by a black color on the satellite image, showing a high density of pine but it is partial and particularly affects reforested areas. The estimated forest area during this period is 808 hectares with an increase of about 3, 6%. In 2009, the degradation affected the entire reforestation except the southwestern part of which 20 hectares of the recorded area in 2001 has disappeared. Despite the choice of the essence of Aleppo pine plantations in this species has not been spared by the plant pathology diseases and insect attacks, particularly the periodic outbreaks of the processionary moth, *Thaumetopoea pytiocampa*. For that purpose we have to choose the most resistant varieties to phytopathogenic diseases

Case of Moudjbara Plantation

Within the programs of Moudjbara project plantation was launched from the eighties. The satellite image from 1987 shows the beginning of stand growth; these young subjects are represented by the light green color and occupy a calculated approximately 9990 hectares.

The year 2001 was marked by considerable degradation and mainly affects subject's edges and the center of the plantation. The subjects of this population are completely stunted and poorly developed, which is appeared on satellite images from 2001 and 2009. This degradation is almost the entire recorded area in 1987; about 7491 hectares have disappeared in 2001. Moreover in 2009 the recovery is remarkable in digitization, but inside reforestation very low density with a random distribution of the decline and degraded subjects. This degradation is confirmed by observations and surveys carried out within the reforested area. Degradation mainly concerned the eastern part of reforestation where the majority of the tree surface has disappeared and a very reduced in the western part of the forest mass. These forest traces reflect and justify evaluation difficult subjects during the last decade, which gives another picture of decay and degradation of the forest cover. This is due to declining anthropozoïques and ecological factors. Degradation has affected much in the Djelfa area forest. Stands of Djellal Guarbi El Oust, El gueddid El oughba and Degdegue, have very limited compared to the total forests losses.

Cartographic Analysis of the Area Decline

The analytical observation of considered images, bearing the geographical coordinates of the most degraded on the site of the forest Senalba Chergui areas, show that these points are subjects occupying the edges of the forest, and focus particularly on the part north of this forest formation, indicating that this area remains temporally threatened by decay.

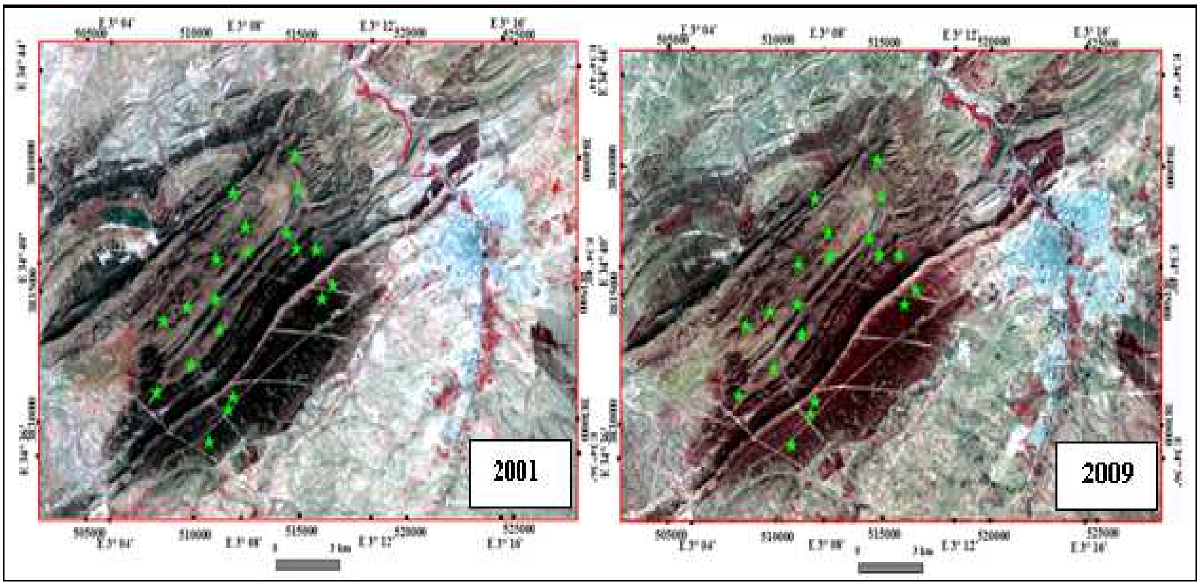

Figure 3: Satellite Images Showing Areas in the Decline Forest of Senalba Chergui

Image of 2001, the southwestern part of the forest carries a large number of the decayed subjects, which are the results of the surveys conducted in the geographic coordinates in the year 2013. The image of the 2009 has a contour gradient larger around these points; the degradation is moving in any direction of the forest reserve and extends over a large forest area. The light brown color reflects a gradient and sparse population; the bare areas are presented especially the northern part. The health status of each subject does not really manifest itself on the satellite image, which determines the declined forest masses. Subsequent survey results on field inform us that the decline is actually more important than the satellite image presents these results were provided by BENCHERIF (2010) which consists in mapping the floristic structure of Senalba Chergui forest. General damages are highlighted in space and time and require a stricter and rational protection of forest stands in their entirety.

The diachronic analysis based on the mapping of satellite images covering landscapes of Djelfa area over thirty-seven years, highlights the identification of spatial and temporal dynamics of this forest area. During the eighties the evolution of the forest cover is significantly positive result by floristic development. According to data collected from satellite images, since 2001, degradation is worrying and remains such as over time. The comparison of the collected field data and the results from satellite images provided data regressive forest surfaces.

In 1987 the forest cover mapping represents 22% of forest area in Djelfa region, with an area of 70391 hectares. This area has declined since 2001, with a decline of about 11376 hectares, adding that 24% of the forest area recorded in 1987 disappeared in 2009, a loss of 17107 hectares.

The digitalization of forest areas and on field surveys demonstrate that the forests of Senalba Chergui are most at risk, and the North Slope is the most vulnerable to degradation. In reality actually deteriorated homes are more significant because the affected stands within forests cannot be removed from the digitized surface.

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APPENDICES

Table 2: Geographical Coordinates and Position of the Most Degraded on the Site of the Forest Senalba Chergui

Points	Altitude(m)	Latitude(N)	Longitude(E)
P1	1320	34°37'08.1"	03°08'20.6"
P2	1325	34°36'41.1"	03°07'26.2"
P3	1327	34°36'25.4"	03°06'17.0"
P4	1343	34°36'28.8"	03°06'03.6"
P5	1328	34°36'15.5"	03°06'34"
P6	1339	34°36'53.3"	03°05'15.1"
P7	1324	34°37'15.2"	03°05'27.7"
P8	1350	34°37'21.8"	03°06'18.9"
P9	1351	34°37'03.2"	03°05'35.8"
P10	1366	34°37'40.1"	03°07'42.0"

Table 2 : Contd.,

P12	1153	34°43'17.7"	03°09'21.1"
P13	1154	34°43'18.2"	03°09'10.3"
P14	1164	34°42'37.4"	03°09'20.0"
P15	1134	34°43'06.8"	03°08'54.11"
P16	1160	34°42'31.8"	03°07'48.4"
P17	1201	34°42'21.3"	03°08'57.5"
P18	1213	34°41'54.5"	03°08'17.3"
P19	1219	34°42'09.8"	03°08'26.4"
P20	1214	34°41'10.48"	03°09'7.0992"
P21	1214	34°41'49.71"	03°06'19.8756"